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Thesis

PARASITIC COPEPODS OF THE FAMILY SPHYRIIDAE WITH SPECIAL REFERENCE TO THE INTERNAL ANATOMY OF THE REDFISH PARASITE, SPHYRION LUMPI (KRØYER 1837) BASSETT-SMITH 1899

by

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INTRODUCTION

From a parasitological viewpoint, the Subclass Copepoda Latreille 1831 is an interesting and important group both in regard to serving as intermediate hosts for various helminths and also as true parasites of fish. The interest of this paper is in the parasitic habit which has been adopted by the various members of the family Sphyriidae Wilson 1919. Various members of this family were described as early as 1829 (Guérin-Méneville) during a period when descriptive anatomy and speciation were proceeding at a rapid rate. Many of the proposed species and genera of parasitic copepods were placed in wrong or unsuitable classifications. To criticize the early investigators for their many errors in classification is certainly unjust, since the present-day classification of parasitic copepods is based largely on structures of the early developmental forms which were not known to them. Indeed, a further knowledge of the life cycles and embryology of these parasites would probably not only alter the present-day classification but would certainly indicate or establish relationships among the various families.

An attempt is made in the first part of this thesis to review all the literature concerning the members of this family which are parasitic on marine fishes. The characters of all the species and genera of all the investigations have been presented and an attempt has been made to determine the validity of some species. Comparative tables have been compiled for both the male and female of all the genera.

The second part of the thesis is devoted to an internal anatomical and histological description of the female of the redfish parasite,

Sphyrion lumpi(Krøyer 1837) Bassett-Smith 1899, which is one of the most extremely modified parasites of this family. The description and figures are based on serial sections of specimens of the parasite which were taken from redfish brought to the Boston Fish Pier in October 1948.

I. Review of literature on the parasitic copepods of the family Sphyriidae

A. Historical account and classification of the family

Before Wilson (1919) established the family Sphyriidae, the genera now included in this family were listed in the family Lernaeidae, a depository for all bizarre copepods. However, the genera forming the family Sphyriidae have certain common morphological features and a life history which is entirely different from those in the family Lernaeidae. These features include posterior processes and ovisacs arising from the posterior part of the trunk, degenerate mouthparts, and no swimming legs in the adult female. The male is attached to the posterior part of the female's body. The naupllius and metanauplius stages are passed within the egg. In Paeon elongatus Wilson 1919 the metanauplius escapes from the egg and molts into the first free-swimming or copepodid stage. This manner of development has been assumed for the other members of the family and is identical with the development of the members of the Lernaeopodidae. The Sphyriidae were formerly considered as relatives of the Lernaeidae and were placed in the suborder Caligoida Sars 1901. However, Wilson(1932) observed that the copepodid stages of Paeon elongatus Wilson 1919 had a coiled frontal filament which is characteristic of the Lernaeopodidae. He therefore placed the Sphyriidae in the suborder Lernaeopodoida. The present classification of this family is: Superclass Crustacea Pennant 1777, Subclass Copepoda Latreille 1831, Suborder Lernaeopodoida Stebbing 1910, Family Sphyriidae Wilson 1919.

The family includes six genera: Opimia Wilson 1908, Paeon Wilson 1919, Periplexus Wilson 1919, Trypaphylum Richiardi 1878, Rebelula Poche 1905, and Sphyrion Cuvier 1839. The number of known species is twelve, each of which will be described in the sections on the genera and species.

B. Features of the family

Family characters of the female

The cephalothorax is usually soft and bears lateral processes. The neck is slender and in all genera except Opimia bears chitinous processes, horns, or knobs. The trunk is flattened dorso-ventrally and on both the dorsal and and ventral surfaces bears pits which coincide with the points of attachment of the dordo-ventral muscles. The abdomen in the adult is completely fused to the trunk, but the anal laminae are always present. A pair of posterior processes arise from the posterior portion of the trunk. The ovisacs or egg-strings are long and narrow, and the eggs within are arranged in series or succession. The mouth tube is usually protrusible. Two pairs of antennae, two pairs of maxillae, and one pair of maxillipeds are always present in the young forms, but in the adult all of the head and mouth appendages are reduced to small knobs. The gut is straight in all species, leading from the mouth to the anus. There are no intestinal processes except in the species of Rebelula and Sphyrion. The oviducts are coiled and are usually separated by strands of dorso-ventral muscles whose contractions help the eggs along the oviduct. Both the ovaries and the cement glands are paired and are situated along the lateral margins of the trunk, the ovaries lying immediately in front of the cement glands.

Family characters of the male

The body form of the male is usually folded and in two parts, the cephalothorax and the trunk. The cephalothorax contains the mouth tube and mouth appendages; the trunk bears no appendages. The body is indistinctly segmented in all genera except Sphyrion, which shows no external segmentation whatsoever. The head and mouth appendages include two pairs

of antennae, two pairs of maxillae, and one pair of maxillipeds whose basal joints are always fused along the midline. The gut runs straight through the body. A pair of testes are situated in the dorsal part of the cephalothorax and usually show external swellings. A straight vas deferens leads from each testis and along the way to the outside is surrounded by cement glands. Each vas deferens enlarges into a spermatophore receptacle at the posterior part of the trunk. A large excretory gland is located at the base of the fused maxillipeds. Small glandular bodies surround certain portions of the digestive tube.

In summary, the distinguishing features of the family Sphyriidae are the presence of the adult pigmy male attached to the female which buries its head and neck into the tissue of the host, the lateral processes on the cephalothorax of the female, the posterior processes arising from the posterior portion of the trunk, the chitinous neck in the females, the position and arrangement of the reproductive organs of both sexes, the dorso-ventral muscles separating the convolutions of the oviducts, the entire absence of swimming legs on the adults of both sexes, the fusion of the basal joints of the maxillipeds of the males, and the complicated arrangement of the intestinal processes in the genera Rebelula and Sphyrion.

C. An account of the genera and species

1. Genus Opimia Wilson 1908

This genus contains only one species, Opimia exilis, which was described by Wilson in 1908. (Fig. 1). It was taken from the soupfin shark, Galeorhinus zyopterus Jordan and Gilbert 1816, off the coast of California. The male is unknown.

The characters of the genus are a spherical head, stout neck, depressed body, no horns or processes on either head or neck, and two long posterior processes which are unbranched and not covered with respiratory cones or cylinders.

Wilson(1908) described the female of the species Opimia exilis with the following features. The form of the body is long and slender with no visible segmentation. The cephalothorax is spherical with no horny pcocesses. The neck is cylindrical with no processes but is somewhat wrinkled at its junction with the trunk. The diameter of the neck is consistent throughout its length which is about two-thirds the length of the entire parasite. The trunk is relatively narrow and has a pair of processes at its posterior end. These posterior processes are cylindrical, smooth, straight, and do not have respiratory cones or cylinders. The abdomen is reduced to two very small knobs.

The first pair of antennae are made up of a single joint. The second pair of antennae are stouter but still uniramous. There are one pair of maxillae. The maxillipeds are strongly developed and each is tipped with a strong claw. The mouth tube is terminal in position. According to the description given by Wilson (1919), the parasite has one pair of swimming

legs directly behind the maxillipeds. From this it can be concluded that Wilson was probably describing the immature forms since the adults of the other members of this family never have swimming legs.

The genus Opimia as established by Wilson is closely related to the genera Trypaphylum and Paeon. These three genera differ from Rebelula and Sphyrion by the fact that their posterior processes are not branched and have no covering of respiratory cones or cylinders.

The distinguishing features of the genus are the smooth cephalothorax without processes or horns and stout maxillipeds. Opimia is the only genus of this family that lacks chitinous growths on the neck.

2. Genus Paeon Wilson 1919

This genus includes three species described by Wilson (1905, 1919). All were found on the mouth or gill cavities of sharks, the head and neck of the parasite being buried into the flesh of the fish, the ovisacs and posterior processes hanging free.

The characters of the genus are the globular processes on the head, the slender, cylindrical, neck, and a pair of long posterior processes which are dorsal to the ovisacs at the posterior part of the trunk.

Paeon ferox Wilson 1905 has been found on various sharks. (Fig. 4).

Characters of the female

The cephalothorax is enlarged transversely into a pair of hemispherical processes which bear on both the dorsal and ventral surfaces several pairs of knob-like protuberances. The mouth tube is protrusible and is located between the bases of the first pair of knobs on the anterior margin of the head. At either side of the mouth tube near its base are the first and second pairs of maxillae, both armed with claws. These are the chief organs of prehension. The neck measures about one third the body length and shows some signs of external segmentation. The neck is somewhat enlarged where it joins the trunk and shows many transverse wrinkles at this point. The trunk is about three times as long as wide, and widens posteriorly. Its surface is smooth except for numerous pits which are the points of attachment of the dorso-ventral muscles. The abdomen is not visible but Wilson says that there are indications of it in the breaks of the longitudinal muscles, showing that the posterior processes arise from the dorsal surface of the abdomen. Each posterior process is about the length of the trunk, cylindrical in shape and consistent in diameter throughout. The

anal laminae are two small knobs at the posterior portion of the trunk and lie at the bases of the posterior processes. The ovisacs are also cylindrical, each attached to the inner margins of the anal laminae. Their diameter is two-thirds that of the posterior processes but are a little longer in length.

Although Wilson gave no figures of the internal anatomy , he gave a description from studied material. There are present two ovaries, one on either side in an anterior lateral position of the trunk. Each ovary is situated anteriorly to a cement gland. Extending from each ovary is a long coiled oviduct which is interwoven with strands of dorso-ventral muscles, whose contractions apparently help the eggs along the oviduct to the vulva. The cement glands are situated laterally in the trunk, each directly behind an ovary. Each cement gland gives off a duct which opens into the oviduct a short distance behind each vulva. The mouth tube leads directly to the esophagus which passes to the stomach. The stomach lacks processes, becomes very narrow, and passes into the intestine. This is at first narrow, but enlarges upon entering the trunk, and then passes to the short rectum which opens between the inner surfaces of the anal laminae.

This species is found attached to the gill tissues of sharks and lies in close proximity to the large arteries supplying the gills. The buried head is covered with small forms such as protozoa and algae which Wilson claimed act as an aid in the attachment of the parasite. The neck and head are both enclosed by a sheath of tissues of the vertebrate host.

Characters of the male

The body of the male is segmented and the regions are well separated from each other. The cephalothorax is covered with a carapace and makes

up more than one-half of the entire length of the parasite. Immediately behind the cephalothorax there is a free segment followed by three fused segments. No abdomen is visible externally but the posterior part of the trunk is prolonged into two long conical processes, each of which is tipped with a spine. The mouth appendages are located on the sides and base of the mouth tube and consist of two pairs of maxillae and a pair of maxillipeds. Two pairs of antennae are also present.

The testes of the parasite lie in the back of the head and are situated opposite the maxillipeds. From each testis a vas deferens leads along the side of the intestine and then enlarges into a spermatophore receptacle which lies at the posterior end of the thorax.

Paeon versicolor Wilson 1905 occurs on the mouth and gills of various sharks (Fig. 2).

Characters of the female

The cephalothorax is obcordate and bears two processes on its anterior margin. The mouth tube and mouth appendages are similar to those of Paeon ferox. The neck is of uniform diameter and is completely wrinkled. The trunk is flattened dordo-ventrally. The surface of the trunk is completely smooth and does not bear scattered pits as in ferox. The abdomen is not visible externally but is indicated internally by the breaks in the longitudinal muscles. The anal laminae are large, appearing as knobs on the ventral surface of the posterior part of the trunk. The ovisacs arise from the inner surfaces of the anal laminae. The posterior processes are sausage-shaped, shorter than the ovisacs, and arise from the posterior part of the trunk. The internal anatomy is similar to that of ferox.

Characters of the male

The cephalothorax of this species is extremely large and has a rounded carapace. The second thoracic segment is free but the rest of the segments are completely fused. The posterior processes at the end of the trunk are shorter than those found on ferox and tipped with spines. The mouth tube is similar to that found in ferox. The head and mouth appendages include two pairs of antennae, two pairs of maxillae and one pair of maxillipeds. The reproductive organs are similar to those of ferox, consisting of testes, sperm ducts or vasa deferentia, and spermatophore receptacles.

The third species, Paeon elongatus Wilson 1919, was found off Marthas Vineyard attached to the gills of the brown shark, Carcharhinus milberti Jordan and Gilbert , but also occured on the dusky shark Carcharhinus

obscurus Le Sueur (Fig.9).

Characters of the female

The head is enlarged, spherical in shape, and bears on its ventral surface several pairs of knobs. Between the inner surfaces of the most anterior pair of knobs lies the retractile mouth tube. The head and mouth appendages include the maxillae which are situated along the sides of the mouth tube, and the second antennae which also lie at the sides of the mouth tube. The neck is smooth or wrinkled, half as long as the trunk and is wrinkled transversely at its union with the trunk. The trunk is club-shaped, the anterior portion being more narrow. The surface of the trunk is smooth and shows no pits of attachment of the dorso-ventral muscles, except when the latter are contracted. From the dorsal surface of the posterior part of the trunk arise two posterior processes which are about the length of the trunk itself. They increase in diameter posteriorly and are curved at their tips. The ovisacs also arise from the dorsal surface above the posterior processes and although their diameter is only one-half that of the processes, they extend about five times the length of the posterior processes. The ovisacs measure from 20-25 mm in length and each is estimated to contain about 1000 eggs.

Characters of the male

The cephalothorax is about one and a half times longer than the trunk and its dorsal surface is covered by a carapace. The abdomen is lacking, but at the posterior end of the trunk are two caudal rami in front of which are two short processes. Two pairs of antennae, two pairs of maxillae, and a pair of maxillipeds are present. The total length of the male is 1.6-1.8mm.

In summary, the three species of Paeon have the following features:

1. ferox- head enlarged transversely and elliptical in shape, neck

smooth, trunk longer than wide and truncated posteriorly, ovisacs and posterior processes about the same length.

2. versicolor- head obcordate, neck wrinkled, trunk flattened dorso-ventrally and as wide as long, ovisacs and posterior processes about the same length.

3. elongatus- spherical head, relatively smaller body, ovisacs five times the length of the posterior processes.

Wilson (1919) found that two adult elongatus females had ripe eggs. These eggs were placed in an aquarium and were later hatched. The embryos obtained were the first to be observed of any species of the Sphyriidae. Wilson stated that the nauplius and metanauplius stages are passed within the egg that at the time of the first copepodid or free-swimming stage, the metanauplius escapes from the egg and molts into the fist copepodid stage.

The metanauplius larva has a stout ellipsoid body. The head and first segment are fused. A pair of caudal rami extend from the posterior end of a well-developed abdomen. The metanauplius has two pairs of antennae, two pairs of maxillae, and one pair of maxillipeds. There are also two pairs of swimming legs which are rather rudimentary.

After the metanauplius escapes from the egg and molts, it forms the first free-swimming or copepodid stage whose head is ellipsoid and twice as long as wide. The body is elongate. The antennae, maxillae, and maxillipeds all extend beyond the anterior portion of the head. There is a coiled frontal filament which extends from the anterior portion of the head Wilson (1932 plate 31.) This coiled frontal filament is so characteristic of the Lernaeopodidae that it was mainly because of this structure that the family Sphyriidae has been placed into the suborer Lernaeopodoida. The mouth

appendages of this stage are similar in structure to those of other Lernaeopodidae. There are four body segments behind the head, the first two being thoracic segments bearing swimming legs. The third segment is the genital segment which becomes the trunk in the females. The fourth segment is the abdominal segment which bears the caudal rami. Each swimming leg is made up of a basal portion of two segments. Arising from the distal segment are two one-segmented rami. The described copepodid stages of Wilson measured from 0.5-0.6 mm.

3. Genus Periplexus Wilson 1919

This genus contains only one species to date, Periplexus lobodes, which was described by Wilson in 1919 (Fig. 3.). The genus and species were determined from a single female collected in 1883 from a deep sea fish, Aleopocephalus agassizii Linck 1867, taken from the coast of New Jersey. The male of the species is unknown.

The characters of the genus are a wrinkled head, a twisted neck having short chitinous processes, and cylindrical, smooth , posterior processes, each composed of three distinct segments.

Characters of the female

The cephalothorax is cylindrical and shows transverse wrinkles. The neck has a smaller diameter than the head and is bent and twisted. It bears numerous horns and processes all of which are chitinized but none are branched. The trunk is elongate, and flattened dorso-ventrally having a row of pits along the lateral margins of both the dorsal and ventral surfaces. The anal laminae are divided on the ventral surface into three lobes which lie above the bases of the ovisacs or egg-strings. The abdomen is minute and shows fusion with the trunk. The posterior processes, differing widely from those of the other species of this family are made up of three large lobes whose adjacent surfaces are flattened together. The posterior processes attach to a groove between the abdomen and the anal laminae, and at the point of attachment narrow into a short tube. The ovisacs are longer than the trunk and their diameter is about two-thirds that of the posterior processes.

The anterior surface of the head is truncated and has two crescent-like pads enclosing a mouth tube which is retractile. The specimen as described

by Wilson showed rudiments of first and second antennae and the first pair of maxillae along the side of the mouth tube. Each of the maxillae was tipped with a spine. The specimen was found with its head and neck buried into the flesh of the fish. Since there was only one available specimen, the internal anatomy was not studied.

Although only one available specimen constituted the new genus and species, their validity can be established by such distinguishing characters as an intricately twisted neck, and posterior processes made up of three lobes. It is interesting to note that although the species of Rebelula and Sphyrion have increased the surface area of their posterior processes by branching and subdivisions or attachment of respiratory cones or cylinders, Periplexus has attained greater surface contact with the water by increasing the diameter of the processes themselves.

4. Genus Trypaphylum Richiardi 1878

This genus contains only one known species, Trypaphlum musteli, which was first described by van Beneden in 1851 with a figure of the male and a figure of the female (head lacking) (Fig. 6). Van Beneden's specimen was taken from the gills of the smooth hound, Mustelus vulgaris Mitchill 1790, off the Belgian coast. The parasite was called Lereonema musteli by van Beneden, but was renamed Trypaphylum by T. and A. Scott in 1913.

The characters of the genus are a head with stiff cartilaginous horns, a neck filiform anteriorly and widened posteriorly, and two posterior processes ventral to the ovisacs. It was commonly found attached to the gills of Mustelus vulgaris in the Irish Sea.

Characters of the female

The body is slender, elongate, and shows no signs of external segmentation. The head is round with stiff cartilaginous horns. The neck is narrow anteriorly but widens posteriorly. Van Beneden described the neck of his specimen as red in color remaining red even after the specimens were put into the fixative. T. and A. Scott (1913) make no mention of prevailing red color in their description of the species. The trunk is narrow anteriorly but widens posteriorly. At the posterior end of the trunk are two slender posterior processes which are straight, smooth, and cylindrical, just as in Opimia and Paeon. Although the ovisacs have no connections with the posterior processes, they originate at the base of the latter and extend backward to a length twice that of the posterior processes. The body length as given by van Beneden, exclusive of the abdominal appendages, measures 45 mm. No description of the internal anatomy was given.

Milne-Edwards (1840) described two species of the genus Lerneonema. The first was called Lerneonema sprata, found attached to the eye of a sprat taken from a London fish market in 1848. The second species was called Lerneonema encrasicolor and was also taken from a sprat. Both of the described species had elongate bodies, the heads were swollen, and had stiff cartilaginous horns. The necks were slender, widening posteriorly with some constrictions. Two figures were given by Baird (1850) in plate 35, figs. 11 and 12. The difference between the two species is based upon the neck length, constrictions in the neck, and the length of the ovisacs. Baird believed them to be the same species, and from the description and figures given there is little doubt that both the species are identical with Trypaphylum musteli as established by van Beneden (1851).

Characters of the male

The body of the male is divided into two unequal portions, the anterior part being larger. The posterior portion of the body is narrow and has two knob-like processes which are considered as a fifth pair of legs by T. and A. Scott (1913). The cephalothorax is conical, has no carapace, and shows no external indication of testes. The mouth is terminal and is surrounded by minute setae. The first antennae are uniramous. The second antennae are rudimentary. The maxillipeds are well-developed and are tipped with strong curved teeth. The thoracic region bulges but has a smooth surface. According to the description given by T. and A. Scott (1913), the male has two pairs of legs. Both pairs of legs are biramous and bear hooks at their ends to aid the parasite in clinging to its host. The posterior pair of legs also have hooks at their bases which add for greater adhesion. T. and A. Scott (1913) give exellent figures of the appendages of the male in their plate 59, figs.1-7.

In summary the distinguishing features of the female are the stiff cartilaginous horns of the head, the narrow neck which widens posteriorly, and smooth, cylindrical, posterior processes.

The distinguishing features of the male are the division of the body into two unequal portions, the structure of the head and mouth appendages, and the possession of two pairs of legs.

5. Genus Rebelula Poche 1908

Generic characters of the female

The head is cylindrical and soft. The neck is also cylindrical but narrower than the head. It is fully chitinized and is armed at its anterior end with knobs, processes, or branched horns. The trunk is cordate, flattened dorso-ventrally, and bears at its posterior end a pair of medial lobes which are situated at the bases of the ovisacs. The abdomen is completely fused with the posterior end of the trunk. From the surface of the abdomen arise two branched posterior processes which are covered with respiratory cylinders. The mouth appendages surround the mouth tube and are reduced to small processes in the mature adult.

Internally, the esophagus leads to the stomach which narrows before passing to the intestine. The intestine is at first narrow but widens in the trunk region and passes to a short rectum. Branched processes arise from the intestine where it passes from the neck into the trunk. The ovaries and cement glands are situated in the lateral positions in the trunk segment, the ovaries lying immediately in front of the cement glands. The oviducts are not separated by coils of dorso-ventral muscles as in Sphyrion but are coiled within the cement glands. The dorso-ventral muscles are grouped in the form of bundles both anteriorly and posteriorly. The characters of the males will be described in the accounts of the different species of Rebelula.

Rebelula bouvieri Quidor 1912 is commonly found attached to the flesh of the common grenadier, Macrourus bairdii Goode and Bean 1786, caught off Marthas Vineyard (Fig.11).

Characters of the female

The head is smooth and about four times as long as wide. The neck is straight, fully chitinized, and bears at its anterior end three spherical processes which Wilson (1919) claimed help anchor the parasite to the host. The trunk is cordate and shows depressions on both the dorsal and ventral surfaces which are the points of attachment for the bundles of the dorso-ventral muscles. The anal laminae consist of two double lobes. The oviducts open between the inner surfaces of each double lobe. The ovisacs are comparatively large in diameter and about twice as long as the trunk. In several cross-sections of the ovisac, Wilson found from 75-100 eggs in each section and estimated each ovisac to contain 20,000 eggs. The need for such large numbers of eggs is apparent when one considers that the host of the parasite is a deep sea fish, thus involving difficulty of the copepodid stages in finding a new host. The abdomen of the parasite is fused to the trunk and from it arise the posterior processes, each of which contains from 40-50 respiratory cones. The mouth appendages are all degenerate. The esophagus passes to the intestine and at the point where the intestine passes into the trunk region it gives off numerous processes, finally joining a short rectum. The cement glands and ovaries occupy lateral positions, the ovaries lying directly in front of the cement glands. The oviducts are coiled, but are not separated by coils of dorso-ventral muscles as in Sphyrion.

Characters of the male

The head portion is as long as the rest of the body, has no carapace, but contains two swellings on its dorsal surface which correspond to the

position of the testes. A vas deferens leads from each testis and enlarges into a spermatophore recepttacle at the posterior end of the body. The cement glands surround the sperm ducts in various positions in the posterior part of the body. The genital opening at the posterior end of the body is surrounded by two small knobs. Internally, a large single gland is located at the bases of the maxillipeds. Wilson claimed this gland to be excretory in function. The first and second antennae, the first and second maxillae, and one pair of maxillipeds are present. The total body length measures to about 3 mm.

Rebelula gracilis Wilson 1919 was found attached to the long-nosed eel, Synaphobranchus pinnatus Block 1786, caught off Marthas Vineyard (Fig).

Characters of the female

The cephalothorax is about ten times as long as wide and has at its anterior end a triangular head. The neck is slender, twisted, and armed in several places with chitinized knobs. The trunk is oblong to obcordate and contains several pits on both the dorsal and ventral surfaces. The anal laminae are spherical. The posterior processes are half as long as the trunk and are covered with respiratory cones. The ovisacs are as long as the entire body, their diameter being smaller than that of bouvieri.

The distinguishing characteristics of this species are the triangular head, the long narrow ovisacs, and the twisting neck armed with chitinized knobs.

The male of the species is unknown.

Rebelula cornuta Wilson 1919 was found on the long-nosed eel, Synaphobranchus pinnatus 1847 Baird and Girard ,caught off Marthas Vineyard (Fig.5).

Characters of the female

The neck of this species, which is bent at right angles to the trunk, is armed with characteristic branched, chitinized, horns which are very irregular in size. The trunk is obcordate and flattened dorso-ventrally. The anal laminae are spherical and from them arise the ovisacs which are not visible from the ventral surface, being covered by the posterior processes. At the posterior part of the trunk is a small abdomen from which arise the posterior processes which are covered with respiratory cylinders. The head and mouth appendages are all degenerate.

Characters of the male

The head of the male is truncated at an angle of 45 degrees to the body axis. On this truncated portion are two pairs of antennae, the mouth tube, and the maxillae which lie at the base of the mouth tube. Maxillipeds are present and two short spines are present at the posterior end of the body. On the dorsal surface of the head are two large protrusions which are identical with the position of the testes. A vas deferens leads from each testis into a large spermatophore receptacle at the posterior end of the body. Cement glands surround portions of the vasa deferentia. Near the base of the maxillipeds is a single large gland which is excretory in function (Wilson 1919).

In summary, the distinguishing features of the female cornuta are the branched chitinized horns on the anterior part of the neck, and the

large number of respiratory cylinders covering the posterior processes. The distinguishing features of the male are the oblique truncation of the anterior portion of the head and the large protrusions of the testes.

Rebelula edwardsii (Kölliker 1853) T. and A. Scott 1913, was originally described in the genus Lophoura. Kölliker got his specimens from species of Macrouridae Block 1786 caught off Messina. The Scotts' specimen was taken from species of Macrouridae in the Irish Sea (Fig. 8).

Characters of the female

The cephalothorax is long and wide, the head portion being subcylindrical. The head and mouth appendages are all degenerate. The neck has four unbranched processes at its anterior end at right angles to the axis of the neck. The trunk is oblong and has four depressions an both the dorsal and ventral surfaces. These depressions are the points of attachment of the dorso-ventral muscles, which occur in this species as bundles. At the posterior end of the body is a median lobe which has an additional lobe on either side of it. The Scotts (1913) describe these three lobes as part of the abdomen. Wilson (1919) refers to the median lobe as the abdomen and the two lateral lobes as the genital processes out of which open the oviducts. The Scotts have called all three lobes the abdomen because of the fusion of the abdomen with the genital segment, in which case the two terms become synonymous. However, only the breaks in the internal musculature can indicate the true morphology and neither Wilson nor the Scotts give a description of the internal structures. The ovisacs are long and arise from the base of the abdomen. Also arising from the

two posterior processes which are covered with respiratory cylinders. The male of the species is unknown.

In summary the distinguishing features of this genus are as follows: In the female - a soft, cylindrical or subcylindrical cephalothorax, a narrow neck region armed with chitinized knobs, processes or horns, posterior processes which are covered with respiatory cylinders, and processes off the intestine where the latter enters the trunk region. In the male - enlargement of the testes on the dorsal head surface, and oblique truncation of the anterior portion of the head.

6. Genus Sphyrion Cuvier 1839

Generic characters of the female

The cephalothorax, from whose anterior surface projects the head, is expanded with lateral processes. The neck is usually straight, long, and chitinized. The trunk varies in shape but is flattened dorso-ventrally. Pits may occur on the dorsal and ventral surfaces depending on whether the dorso-ventral muscles are contracted. The small abdomen is at the posterior end of the body and is bilobed. A pair of posterior processes arise from the lateral surfaces of the abdomen and are profusely branched. The ovisacs are long and straight. Two pairs of antennae, two pairs of maxillae, and one pair of maxillipeds are found in the young forms but these appendages degenerate to small knobs in the adults. Internally, the convolutions of the oviducts are separated by strands of dorso-ventral muscles. In the trunk, several rows of intestinal processes arise from the dorsal and lateral surfaces of the intestine.

Generic characters of the male

The body form of the male is ellipsoid and is divided into cephalothorax and trunk with no apparent segmentation. A small carapace covers the cephalothorax. A mouth tube is present with two pairs of antennae, two pairs of maxillae, and one pair of maxillipeds whose basal joints are fused. Internally the esophagus passes to the stomach which narrows into the intestine, following the contour of the body and opening behind the maxillipeds as the anus. The testes lie at the base of the maxillipeds. Leading from each testis is a sperm duct which coils back and forth and forms a large spermatophore receptacle before opening to the outside.

There have been several species proposed in this genus: australicus, delagei, kingi, kroyeri, laevigatum, lumpi, and stewarti, and it is still a matter of opinion whether all of these are distinct species. That lumpi and laevigatum constitute definite species is certain but there is still doubt whether kingi is a species or is synonymous with laevigatum. The other proposed species are probably all variations of laevigatum, since most of them were described from a single specimen and the descriptions given were neither accurate nor detailed. Wilson thinks that all the proposed species of this genus can be grouped as either laevigatum or lumpi but Leigh-Sharpe (1928) is of the opinion that kingi has enough variations and distinguishing features to constitute a valid species.

Sphyrion laevigatum Guerin-Meneville 1829 was taken from a fish, Genypterus blacodes Wood 1820, caught off New Zealand.(Fig.10).

Characters of the female

The cephalothorax has two large lateral expansions which taper toward the ends. The expansions are provided with two papillae on the dorsal surface and two papillae on the ventral surface, the former being farther from the mid-line than the latter. The neck is stout and shorter than the trunk. The trunk is bulbous, much wider than long, and is flattened dorso-ventrally. From the surface of the prominent abdomen arise the posterior processes which are finely divided and bunched into three distinct series. The ovisacs arise from the dorsal surface of the abdomen and are longer than the entire body. The head and mouth appendages are all rudimentary in the adult.

The male of the species is unknown.

Brian (1917) gives an exellent description of this species. Stebbing (1900) also described this species and gave an exellent plate. The descriptions and figures given leave no doubt that the above three men were describing the same species. Thompson (1890) gave a very superficial description of a New Zealand specimen which he called kroyeri. From a single specimen Thor (1900) described a specimen from Austalia and gave to it the name austalicus. Quidor (1912) described a single specimen as delagei. Quidor (1912) again gave an account of a species which he called stewarti. Since the body dimensions and growth of the parts of the parasites vary with the age of the parasite, and since many of the proposed

species are based on the dimension factor, together with the fact that some of the proposed species were described from a single specimen, sometimes with the head lacking, as in the case of stewarti, all of these species are probably variations of laevigatum. Table III (after data by Wilson) shows that the grest variations in the body of laevigatum could include all the described species except lumpi. Cunningham (1871) described a species which he called kingi. It was taken from the flesh of a fish at the east entrance of the Straits of Magellan. The description was very poor but he claimed that his specimen differed from laevigatum by a greater body width and greater width of the head region, which he called the sucking disc. The figure which he gave was poor and showed six marginal processes instead of four.

Stebbing (1900) described a species from South Africa as laevigatum, but Leigh-Sharpe (1928) interpreted Stebbing's description and figures as coinciding with Cunningham's species and constituting a new species, viz. kingi. However Wilson (1919) did not believe kingi to be a new species. In Leigh-Sharpe's description of kingi, the lateral expansions of the cephalothorax are not as long and as tapering as in laevigatum. A pair of processes are present on both the dorsal and ventral surfaces of the lateral expansions. The posterior processes are finely divided but are not grouped into series as in laevigatum. The ovisacs are much shorter than those of laevigatum. The neck in kingi is shorter than in laevigatum but Stebbing (1900) claims the neck grows shorter with age and therefore this cannot be considered as a distinguishing specific character.

It is still a matter of opinion whether kingi constitutes a separate

species. The best method of species differentiation is the study of the mouth appendages in the young females or in the males, both of which are very rare.

Table I (after Wilson)

Proposed species of the genus Sphyrion

(measurements in millimeters)

Species	Hammer		Neck		Trunk		Ovisacs	
	length	width	length	width	length	width	length	width
lumpi	13-16	10	15-35	2.5	12-16	12	20	2.5
laevigatum	15-60	4-20	7-12	1-3.5	9-12	9-28	26	2
australicus	20	2-8	7	1-2	10-12	15	30	2.5
delagei	25	11	7	1-2	9	15	20	2.5
stewarti	head lacking		10	5	12	14	30	2
kingi	21	7	4	1.5	14	17	37	2
kroyeri	54	10	12	1-3.5	11	18	25	2

Sphyrion lumpi (Krøyer 1837) Bassett-Smith was first reported from the flesh of Anarrhichas lupas Linnaeus 1758, a fish caught off the Danish coast. Steenstrup (1869) reported it on fish taken from the Danish coast. T. and A. Scott (1904) reported it on fishes taken from the North Sea. Wilson (1919) and Nigrelli and Firth (1939) reported it on the red-fish, Sebastes marinus Linnaeus 1758, caught off the coast of New England.

Characters of the female

The cephalothorax is expanded into lateral expansions which are about the width of the trunk (Fig.12). The neck is longer than the trunk and is usually bent at obtuse angles to the flattened axis of the trunk. The trunk is obcordate and flattened dorso-ventrally, the width and length being approximately the same. At the posterior end of the trunk are a pair of anal laminae from which arise a pair of posterior processes, which in the mature forms are profusely and dichotomously branched. The ovisacs are long and straight. Because of the torsion of the parasite, the diameter of the head is nearly at right angles to the diameter of the neck. A mouth tube is present . Two pairs of antennae, two pairs of maxillae, and a pair of maxillipeds are present in the young forms but all of these appendages are degenerate in the adults.

Internally there are five rows of processes arising from the intestine, three rows dorsally and two rows laterally. The ovaries and cement glands are both situated laterally in the trunk, the ovaries lying immediately in fron of the cement glands. The oviducts are separated by strands of dorso-ventral muscles, and according to Wilson (1919) the contractions of these muscles help the eggs along the oviducts.

Characters of the male

The head is separated from the trunk and is covered by a small carapace. The trunk folds upon itself and there is complete fusion of the segments. The abdomen or genital processes are not visible. The head and mouth appendages are well-developed in the male, consisting of first and second antennae, first and second maxillae, and a pair of maxillipeds whose basal joints are fused. The total length of the male is 2 mm, the width 1 mm.

Although the life cycle of this species is not well known, Nigrelli and Firth (1939) claimed that the only infective stage is the copepodid stage of developement. The young forms have very recognizable mouth appendages, especially the maxillipeds, and it is by means of these structures that the immature forms are able to crawl around on the surface of the host. Once the female buries into the host the mouth appendages of the parasite become degenerate. The male is found either attached to the female or to the flesh of the host. The parasite probably penetrates the host by means of its mouth appendages and also by secretion of digestive fluids from the digestive and secretory glands (Nigrelli 1939). The purpose of burrowing is an attempt to reach the blood vessels of the host in order to feed upon the blood. Digested blood in the intestine was reported by Nigrelli and Firth (1939).

The external characteristics of the females of the genera and the external characteristics of the males of the species are given on Table I and Table II.

Table II

External Characteristics of the Genera of the Sphyriidae (females)

Genus	Cephalothorax	Neck	Trunk	Posterior Processes	Ovisacs	Hosts
Opimia	spherical, no horny processes	cylindrical, no processes, somewhat wrinkled at junction of trunk	relatively narrow as long as neck	cylindrical, smooth, straight, no respiratory cones or cylinders	not observed	soupfin-shark Galeorhinus zyopterus Jordan and Gilbert 1816
Periplexus	cylindrical with transverse wrinkles	bent and twisted with numerous chitinized unbranched horns	elongate to cordate flattened dorso-ventrally, rows of lateral pits on both dorsal and ventral surfaces	three-lobed, no respiratory cones or cylinders	longer than trunk two-thirds diameter of posterior processes	deep sea fish Aleopocephalus agassizii Linck 1890
Trypaphylum	orbicular with stiff cartilaginous horns	slender, cylindrical, widens posteriorly	elongate, narrow anteriorly and widens posteriorly	slender, smooth and straight	twice the length of posterior processes	smooth hound fish Mustelus vulgaris Mitchill 1790
Paeon	transversely ellipsoid, with knob-like protuberances	slender, cylindrical and wrinkled at junction of trunk	elongate, longer than wide	straight, smooth, no respiratory cones or cylinders	cylindrical, consistent diameter throughout	mouth and gills of various sharks
Rebelula	narrow, cylindrical chitinized	narrow, with chitinized knobs	cordate, flattened dorso-ventrally, pits on both dorsal and ventral surfaces	branched and covered with respiratory cylinders	cylindrical, straight	deep sea fishes of family Macrouridae Block 1786
Sphyrion	lateral expansions often lobed, with chitinized horns	thick, stout and fully chitinized, no horns or processes	obcordate flattened dorso-ventrally	dichotomously branched, no respiratory cylinders	long and straight	redfish and Genypterus blacodes Wood 1858

Table III

External Characteristics of the Species of the Sphyriidae (males)

Genus	Species	Body Form	Carapace	External Indication of Testes	Posterior Processes
Opimia	exilis	unknown			
Periplexus	lobodes	unknown			
Paeon	ferox	distinctly segmented, free segment immediately behind cephalothorax	covers cephalothorax	none	two prolonged conical processes
	versicolor	cephalothorax extremely large, all segments except second thoracic which is free	round	none	same as ferox but shorter and tipped with spines
	elongatus	segments fused, cephalothorax is 1,5 times longer than trunk	covers cephalothorax	none	two short processes
Trypaphylum	musteli	divided into two parts, anterior portion larger	absent	none	two knob-like processes
Rebelula	bouvieri	segmentation indistinct, cephalothorax longer than rest of body	absent	prominent	pair of tiny knobs
	cornuta	head truncated at 45° to body	absent	prominent	pair of spiny processes
	edwardsii	unknown			
	gracilis	unknown			
Sphyrion	lumpi	head separate from trunk, trunk folds upon itself complete fusion of segments	small	none	none
	laevigatum	unknown			

II. The internal anatomy of the redfish parasite, Sphyrion lumpi (Krøyer 1836) Bassett-Smith 1899

A. INTRODUCTION

Although many papers have been written on the anatomy of parasitic copepods, not enough attention has been given to the internal anatomy, especially the histology of the internal organs.

The internal anatomy of the redfish parasite, Sphyrion lumpi (Krøyer) has been described by Wilson (1919) and by Nigrelli and Firth (1939). The description of Nigrelli and Firth is general and gives no figures of the internal anatomy except for one section through the cephalothorax showing the envelope of host tissue around the head region of the parasite. The description by Wilson is supplemented by two sketchy figures and gives no particular attention to the histology of the internal organs.

The internal anatomy of the redfish parasite S. lumpi seems of particular interest not only because of the growing redfish industry which has amounted to an annual catch of 50,000,000 pounds in recent years but also because of the extreme modifications of the copepod in relation to its parasitic existence.

It should be mentioned that this investigation deals only with the female of the species, the pigmy male having been observed and described only by Wilson (1919).

B. MATERIALS AND METHODS

The specimens used in this investigation were taken from redfish brought to the Boston Fish Pier during the first two weeks of October, 1948. The copepods were taken at random during the unloading of the fish from boat to container, whereupon the fish were sold and taken away immediately by the buyer; therefore a record of incidence was not recorded. During a survey of redfish infections of S. lumpi made by Nigrelli and Firth in 1938-39, thousands of fish were examined. The largest number of parasites recovered from a single fish was six, and the average infected fish contained 1.5 parasites. The infected redfish observed in this investigation had an average of 2-3 visible parasites on each fish. One fish had nine visible parasites, indicating that the infection of the observed catch was relatively high. According to fishermen at the pier, the examined redfish were taken from the vicinity of Georges Bank, a heavy redfish fishing area located at 41°-42° north latitude and 66°-69° west longitude.

Some of the specimens were cut out with the attached flesh of the host, but most of them were excised directly from the host tissue. This was done by making an incision with a fine-pointed scissors along the lateral cephalothorax expansion and then pulling gently on the parasite whereupon the parasite usually came out very easily. The parasites were then put into containers containing three different fixatives, 10% formalin, Bouin's, and Zenker's-formol. The time of fixation was 24 hours. The specimens in formalin were then passes directly into 70% alcohol. Those fixed in Bouin's were washed in 50% and 70% alcohol and then preserved in 70% alcohol. Those fixed in Zenker's-formol were washed in running water for twenty-four hours, then washed further in 35%, 59%, and finally 70% alcohol, iodine being

added to the latter to remove the excess mercuric crystals. All the specimens were treated with boiling hypochlorite of sodium in order to soften the chitin. Each parasite was cut into several pieces before dehydration and infiltration in order to obtain complete dehydration and necessary tissue paraffin infiltration. Care was taken to keep the correct orientation for each segment of the parasite. The tertiary butyl method was used for dehyration. The specimens were infiltrated in paraffin for three hours (three changes) and then embedded. The specimens were sectioned at 8 μ and affixed to slides by means of Mayer's albumen. The following stains were used: Mallory's triple, iron hematoxylin and Harris' hematoxylin with phloxine, van Gieson's and fast green as counter stains. The best standard stain was found to be Harris' hematoxylin-phloxine. The staining schedule for this stain was:

Xylol	5 min.
Absolute alcohol	1 min.
Down alcohol series to water	1 min. in each grade
HaH	3 min.
Wash in water	30 min.
Up alcohol series to 95%	1 min. in each grade
Phloxine	8 sec.
Two rinses in 95% alc.	2 min. in each
Absolute alcohol	2 min.
Xylol	5 min.
Mount in clarite	

C. DESCRIPTION OF THE INTERNAL ANATOMY

1. Body wall

El Saby (1933) describes the body wall of several parasitic copepods of the Chondracanthus and Lernaeopodidae as being made up of three distinct layers. Although Sphyrion lumpi (Krøyer) is in a closely related family, its body wall differs from that described by El Saby for in the latter species the body wall is made up of an outer layer composed mostly of chitin, a middle layer one cell thick whose function is to secrete chitin, and an inner layer which he calls sub-cutaneous mesoderm, made up of a network of cells containing dense nuclei and granules in the cytoplasm.

Serial sections of Sphyrion lumpi (Krøyer) show only two distinct layers. The outer layer is a thick, non-cellular layer which covers the entire body from the lateral expansions of the cephalothorax to the grape-like processes at the posterior end of the body. This layer is generally the same thickness throughout, except in the neck region and anterior portion of the trunk where it is somewhat thicker. At first sight it appears to be a solid layer but is actually made up of several smaller layers which are evidenced by their splitting in several sections and by an alternate staining intensity in sections where the layers are loosely packed. In fresh specimens the entire outer layer is transparent and is strongly chitinized in the neck region and in the trunk. This layer stains a dark red with Harris' hematoxylin and phloxine. With Mallory's triple, it stains a dark blue and with several other stains always stains darker than any other tissue of the parasite.

The inner layer of the body wall is made up of the epidermis which

is a single layer of columnar cells with nuclei concentrated at the bases (Plate 2, fig.16). On their inner side, the cells of the epidermis become extremely narrow and are continuous with the fiber-like processes which extend into and are continuous with the parenchyma tissue of the internal cavities. In many sections, especially through the posterior portion of the neck, the epidermis appears to be stratified but this is due to crowding of the parenchymous and fibrous material upon the inside of the body wall. Just as the outer body wall layer forms the entire outside surface of the parasite, including the posterior grape-like processes, so does the epidermis line the entire body wall, except for the ovisacs which appear during the spawning season and whose histology will be described in the section dealing with the reproductive system.

2. Parenchyma

The parenchyma tissue is found in all the internal cavities of the parasite and probably serves for padding of the internal organs. It is made up of cells with long irregular processes and contains much intercellular space (Plate 2, fig.19). The nuclei of the cells contain many small dark-staining granules and the whole tissue is represented by a mesh-like arrangement.

3. Lateral expansions of the cephalothorax

The internal cavities of the lateral expansions of the cephalothorax are made up of irregular bundles of a spongy material (Plate 3, fig.29). The bundles are packed closely together and each is surrounded by a thin dark-staining membrane. The contents of each bundle is made up of a net-

work of spongy material which at low magnification appears very tightly packed, but upon higher magnification exhibits many interstices. No nuclei are visible but thereare dark-staining spots which probably correespond to the overlapping of the processes of the fiber-like spongy material. In each lateral expansion there is one large bundle near the center and progressively smaller ones toward the periphery.

4. Musculature

The musculature of Sphyrion lumpi (Krøyer) is made up of both dorso-ventral and longitudinal muscles (Plate 4, fig.32). The system is fairly well-developed in the young forms, but in the adult female which has become attached to the flesh of its host, movement is restricted and the muscles have become somewhat simplified. The muscles are of two general types: the dorso-ventral muscles and the longitudinal muscles.

The dorso-ventral muscles are muscle bands imbedded into the outer layer of the body wall and run from both the dorsal and ventral surfaces into the body cavity. In the trunk region, all of these muscles extend between the coils of the oviducts and it is possible that their contractions help the eggs along the oviducts as well as causing pits to appear on both the dorsal and ventral surfaces of the outer layer of the body wall.

There are prominent muscle bands running from the dorso-lateral portion of the head to the maxillipeds and maxillae. Although running in an oblique direction, these muscle bands are actually dorso-ventral muscles which correspond histologically to those bands of the trunk region. Another modification of the dorso-ventral muscles is in the region of the rectum where there are several bands of muscles going from the rectum to both the

dorsal and ventral surfaces of the parasite. The rectal dorso-ventral muscle fibers are especially well-developed in the immature forms. Since in the very young forms there are no posterior grape-like processes, it is probable that the contractions of the rectal muscles serve to suck water into the rectum to aid in the respiratory process.

The longitudinal muscles consist of bands of muscles which run in a lengthwise direction immediately beneath both the dorsal and ventral surfaces of the body. These muscle bands originate in the region where the oblique dorso-ventral muscles extend to the maxillipeds. There are four dorsal bands and four ventral bands. The dorsal bands run posteriorly close together but separate in the mid-trunk region and then meet again to end abruptly just above the rectum. The ventral bands are also four in number and run posteriorly but are widely separated the entire distance except just above the rectum where they come together and end abruptly.

Both the longitudinal and dorso-ventral muscle bands are made up of groups of muscle fibers numbering 10-12 in the dorso-ventral bands and from 16-18 in each longitudinal muscle band. In sections stained with Harris' hematoxylin and phloxine, the fibers are red and the nuclei a deep blue. Each muscle fiber contains several nuclei which are elongate in shape and contain dark staining chromatin material (Plate 2, figs.15 and 17). The fibers are cylindrical and the numerous elongate nuclei are located along the outer margin of each fiber. There is a general resemblance to striated muscle although no striations were observed in sections stained with hematoxylin.

However, in sections stained with Mallory's, the nuclei are faintly

visible and the striations are clearly indicated by alternate dark blue and light blue bands appearing on each muscle fiber.

5. Circulation

An examination of serial sections showed no indication of blood cells or blood vessels. Both Wilson (1915) in an examination of the parasitic copepods of the family Lernaeopodidae, and El Saby (1933) in his investigation of the Chondracanthidae and Lernaeopodidae found no evidence of circulatory organs. However, Wilson suggested that the body fluids circulate in the body cavities by means of contraction of the musculature of the parasite, namely, the peristaltic movements of the gut and the contractions o of both the dorso-ventral and longitudinal muscles.

Although nothing resembling blood was observed in Sphyrion lumpi, this parasite has sinuses both dorsal and ventral to the intestinal tract. These sinuses probably serve as conduction vessels of the circulating body fluid. The sinuses are irreularly arranged in sections through the cephalothorax but sections through the neck region show an arrangement of three small sinuses which run dorsally to the intestine and one large sinus that runs ventrally to the intestine(Plate 3, fig.31). This arrangement continues to the trunk region where the intestine gives off processes. The three dorsal sinuses are gradually blotted out by the enlargement of the dorsal intestinal processes, but the large ventral sinus remains, since the ventral intestinal processes do not reach the ventral body wall. Each sinus is surrounded by a muscular membrane outside of which is parenchyma tissue of the internal cavities.

In the rectal region, irregularly arranged sinuses appear on the dorsal side of the rectum, the ventral sinus becoming small and ending at a point just before the attachment of the rectal muscles. Muscular contraction of the gut seems to exert sufficient force for circulation of the body fluid through the vacuoles and parenchyma tissue of the body cavity. Because the sinuses are surrounded by muscular membranes, the former probably serve as modified circulatory vessels and probably play an important part in the circulation of the body fluids. In many sections, the sinuses contain granular material, loose cells and loose tissue, all being misplaced material.

6. Excretory organs

The excretory organs consist of a single pair of maxilliped glands which are situated in the dorsal part of the cephalothorax in the region opposite to the pair of maxillipeds. Each gland is made up of irregular lobes which cluster in three regions of the gland, two dorsal and one ventral. These clusters become smaller posteriorly until their fusion causes a compact-looking gland (Plate 2, fig.13). Each lobule is oval in shape and consists of two distinct portions. The main part of each gland is made up of a network of cells containing deep-staining oval nuclei. In the center of each gland is a medulla-like arrangement of non-cellular m material which stains more lightly than the outer part of the gland and sends short radiating arms into all parts of the gland. Deep-staining granules of the outer portion of the gland group together in the vicinity of the radiating portions of the gland. Serial sections showed a duct

arising from the ventral surface of one gland. This duct proceeds in the direction of the maxillipeds, but its outlet could not be traced. No duct was observed arising from the other maxilliped gland. The observed duct consists of thin-walled, muscular, material with small, elongate, nuclei. All along the duct appear numerous excretory granules of the same type found clustered around the radiating arms of the inside portion of the gland. The excretory granules probably collect in the outer portions of the gland around the radiating arms and travel to the inside of the gland by means of the radiating arms and then to the outside by means of the excretory duct.

El Saby (1933) mentioned a pair of frontal glands in the dorsal portion of the cephalothorax of certain parasitic copepods. Sections of Sphyrion lumpi showed a pair of small glands in this region. These glands are much smaller than the maxilliped glands and have a duct leaving the ventral surface of each. Neither duct could be traced to its outlet.

7. Nervous system

Wilson (1919) in his study of the parasitic members of the Sphyriidae mentioned the remains of sub- and supra-esophageal ganglia. However, sections of Sphyrion lumpi show what appear to be supra-esophageal ganglia but neither sub-esophageal nor beginnings of ventral nerves were observed.

8. Means of respiration

Sections of young forms of Sphyrion lumpi showed several bands of rectal muscles and it is reasonable to assume that anal respiration is the

case in these young forms. However, as the parasite matures, the rectal muscles become less prominent and at the same time there arise from the posterior end of the body the grape-like processes which are dichotomously branched in the adult females (Plate 4, fig.32). Each bunch coming off a main shaft is made up of the two layers of the body wall and contains parenchymous tissue (Plate 3 , fig.25). The external body layer of the processes consists of a thick layer. Apparently pseudostratified on its inner surface there is a layer of cuboidal epidermal cells. The internal cavities are filled with parenchyma of the same general type found in the internal cavities of the trunk region but containing many more nuclei with clearly defined nucleoli and granulated chromatin. The relative proportion of cell nuclei to cell processes and intercellular space is much greater in the posterior processes than in the parenchyma of the other body regions. Because these posterior grape-like processes hang freely into the water during the attachment of the parasite and because they become profusely and dichotomously branched at a time when anal respiation is being abandoned by growing females, it may be concluded that respiration of the parasite takes place through its posterior processes.

9. Digestive system

The gut of Sphyrion lumpi shows several interesting modifications. There is a short mouth tube, and a narrow esophagus leading abruptly to an enlarged stomach which is separated from the former by sphincter muscles in the region of the maxillipeds. The stomach has several folds in its epithelium and gradually narrows in diameter in the posterior part of the cephalothorax. The stomach and intestine can readily be distinguished since the stomach ahs numerous modified cells in its epithelium which are probably secretory in function. These gland cells stain the same as the stomach epithelium, possess no nuclei but rather many dark-staining granules. Most of these gland cells have loosened themselves from the epithelium and appear in the stomach lumen, although many are seen as part of the stomach epithelium. Although Wilson (1919) stated that only the gut of the trunk region gives off diverticula, serial sections of Sphyrion lumpi show two small diverticula of the stomach in the posterior portion of the cephalothorax. These two diverticular are both lateral and are of the same general appearance and staining reaction as the stomach epithelium. They are in direct communication with the lumen of the stomach. Since digestion probably begins in the stomach region, these two diverticula are probably outgrowths for increasing the digestive surface of the gut. The intestine is very narrow at the beginning of the trunk region. It runs close to the dorsal surface until the beginning of the trunk region. In the neck there are numerous small folds in the intestinal epithelium, which are undoubtedly caused by the extreme torsion of the neck. In the posterior portion of the neck, the intestine becomes quadro-

radiate and then widens in the slightly expanded portion of the neck joining the trunk. The intestinal epithelium in this region appears to contain intra-epithelial glands.

In the most anterior portion of the trunk the intestinal epithelium is thrown into numerous folds and it is in the trunk region that the gut exhibits its greatest modifications. Intestinal processes or diverticula begin as simple outpouchings of the gut and are arranged into five rows in the anterior portion of the trunk. One row arises from the dorsal surface of the gut. A dorso-lateral row and a ventro-lateral row arise on either side of the gut. Each row becomes longer posteriorly and the epithelium becomes very folded. The dorsal row of diverticula eventually reach the inner dorsal surface of the body wall in the posterior part of the trunk. The dorso-lateral diverticula become very branched posteriorly but do not reach the lateral epidermis of the body wall. but rather end in the surroundings of the dorso-ventral muscles and coils of the oviduct. The ventro-lateral diverticula are also heavily branched and almost reach the ventral body wall. They then curl toward the midline where their extremities eventually come to lie partially under the ventral portion of the gut. All rows of the intestinal diverticula become shorter and less branched just before the intestine reaches the rectum.

The rectum is short, rounded, and has a thin-walled epithelium, and ends posteriorly in the anus at the tip of the abdomen.

a. Histology of the mouth tube

The mouth tube consists of a single layer of columnar epitheliual

cells (Plate 3, fig.27). The nuclei are very distinct and each contains a dark staining mass of chromatin material which is usually located in the center of the nucleus. The entire tube is surrounded by a network of parenchyma tissue which acts as padding and probably gives a certain amount of support to the tube. However, the parenchyma does not come into contact with the mouth tube, there being free space between the tube permitting a certain amount of movement.

b. Histology of the esophagus

The mouth tube leads to a very short esophagus which consists of an outer membrane, an inner layer of muscular fibers, and an inner layer of epithelium whose cells are columnar, and in places appear to be pseudo-stratified (Plate 2, fig.18).

c. Histology of the stomach

The stomach region is about twice the diameter of the esophagus and consists of an outer membrane, an inner layer of muscular tissue, and an inner layer of epithelium which exhibits numerous folds.(Plate 3, fig.30). The cells of the epithelium are columnar but along the folded portions appear to be stratified. The most distinguishing feature of the stomach is the large number of epithelial cells which have been modified into secretory cells. These cells have dark staining granules and are observed attached to the stomach epithelium although most of them are found in the lumen of the intestine, indicating their formation in the stomach epithelium and entrance into the lumen of the intestine, where a large portion of the digestive process probably takes place.

d. Histology of the intestine

The cells making up the intestinal epithelium are distinctly columnar with large nuclei generally located at the center of each cell (Plate 2, fig.21). The outer membrane and middle layer of muscular tissue closely encircle the epithelium so that no space remains between the latter and the outer layers. The reverse is the case in the region of the stomach. No secretory cells such as are found in the stomach are observed in the intestine. This observation, together with the small diameter of the intestine, distinguishes the stomach from the intestine of the neck region.

The only part of the neck region in which digestion might take place is in the posterior part before joining the trunk. In this region of the intestine portions of the epithelium are thrown into folds giving the appearance of intra-epithelial glands. The cells making up the epithelial folds appear as empty gland cells whose contents have been emptied into the lumen of the intestine.

e.Histology of the intestinal processes

The complicated system of intestinal processes in the trunk region is made up of an outer membrane, a middle muscular layer, and an inner layer of epithelial cells.(Plate 2, fig.23). All the folds and subdivisions of the processes are complete and involve all the layers of each process as indicated by the juxtaposition of the outer membranes of the outer membranes of two processes which are side by side or one above the other. In addition to the complicated division and subdivision of the intestinal processes, the most noticeable feature of the trunk intestine

is the large number of secretory cells and specifically the thousands of digestive granules which are located all over the epithelium and within the lumen of the processes. These granules stain a golden brown with Harris' hematoxylin and phloxine. The greater part of digestion probably takes place within this vast system of intestinal processes.

f. Histology of the rectum

The rectum is made up of the same layers as the other portions of the gut but its epithelium contains numerous crypts whose cells appear stratified (Plate 2, fig.14). The middle muscular layer sends out muscular strands which are interwoven with the cells of the epithelium. This muscular infiltration of the epithelium together with the attachment of dorso-ventral muscles to the outer membrane of the rectal wall seem to indicate a role in the respiratory process.

In the posterior part of the rectum a clump of loose fecal material was observed filling half of the lumen, and containing many of the digestive granules scattered throughout the intestinal processes. The entire fecal lump was ensheathed by a membrane which stained the same as the rectal epithelium. Other sections through the rectum showed this membrane coming off the free end of the rectal epithelium.

10. Reproductive system

The reproductive organs of the female of Sphyrion lumpi include paired ovaries, paired oviducts, paired cement glands, paired ovisacs, and what appears to be a seminal receptacle.

The ovaries are situated in the lateral positions of the anterior

part of the trunk and consist of rows or filaments of ova, which are strongly coiled and enclosed within bands of parenchymous tissue. Each ovary contains masses of small cells and is connected to a widened oviduct which contains numerous large developing eggs containing many yolk granules and numerous vacuoles. It was not possible to follow the coils of the oviducts. Except for the intestinal processes and the cement glands, the oviducts fill all the body space in the trunk region and open as two pits just before the beginning of the ovisacs or egg-strings. The cement glnads are paired, each lying in a lateral position in the dorso-ventrally flattened trunk. They begin immediately behind each ovary and extend to the posterior end of the trunk. Each gland is shaped like a parenthesis mark, the ends pointing toward the mid-line of the parasite. Each gland is made up of two layers, an outer cellular layer which encloses an inner non-cellular layer or matrix.

From the posterior end of the trunk there is a tubular structure which runs ventrally to the gut and ends blindly below the middle portion of the rectum. This structure may act as a seminal receptacle. However, since no spermatophores were observed and no connection could be traced to the oviducts, it could not be established that the observed structure actually serves as a spermatophore receptacle.

a. Histology of the ovaries

The ovaries consist of ova which are arranged in rows in convoluted tubes.(Plate 2, fig.20). Each ovum retains its identity and sections through the ovary tubes show from 6-8 ova in each section of a single t tubule (Plate 2, fig.22). Each ovum contains a large distinct nucleus,

which, when stained with Mallory's triple, shows dark staining granular chromatin material and a large, distinct, light staining nucleolus usually located at one end of the nucleus.

b. Histology of the oviduct

The walls of the oviducts are made up of a single thin layer of muscular fibers with elongated nuclei. No epithelium is found lining the oviducts. Within the oviducts are many large developing eggs which contain many yolk globules located toward the periphery of each egg and numerous vacuoles toward the center (Plate 3, fig.24). Nuclei are not seen in most of the developimg eggs due probably to the overabunance of and masking by the yolk material.

There is much space between each developing egg and oviduct wall. Sections through one convolution almost always contain only one developing egg. This can be explained primarily because of the large size of the developing egg. It would also seem of great advantage to the parasite to have clear passageway to the external ovisacs. This is best accomplished by a single column of developing eggs in the oviducts rather than a conglomeration of crowding eggs which would cause blockage of the oviducts, especially at the curved portions of the convolutions.

Associated with the mature ova found in the posterior parts of the oviducts are filament cells. These cells have been reported in association with developing eggs of copepods of a variety of families, but no adequate explanation has been given of their origin and function except that they are always associated with mature ova. El Saby (1933) stated

that the origin of these cells is not from the ovaries because they take a different stain. He was describing copepods of a different family, therefore his observations cannot be justly criticized. However, sections of Sphyrion lumpi show the filament cells to stain the same as the ovaries suggesting their possible development from the latter. Also, the walls of the oviducts being a thin muscular layer which stains differently from the filament cells suggests that development from the oviducts is not likely. Further investigation is certainly necessary before any general conclusions can be obtained.

c. Histology of the cement gland

Sections of Sphyrion lumpi showed a pair of tubular cement glands made up of two distinct layers and bordered on the outside by a thin layer of chitin (Plate 3, fig.26). The outer layer is cellular and is thick at the edge lying in the lateral part of the trunk but narrow in the portion of the gland closest to the mid-line of the parasite. It is made up of a homogenous mass of dark staining cells which are arranged in vertical rows from the outside to the inside surface. Numerous vacuoles are observed in this outside layer especially along the inner surface. The entire inner surface of the outer layer is a sheet of non-cellular material ao the same type which makes up the inner part of the gland.

The inner portion of the gland is made up of light staining material which shows no appearance of cells but is rather composed of laminated layers which are arranged concentrically toward the periphery but show no definite arrangement toward the inside. The layers making up the inner

portion of the gland are probably given off successively by the outer layer during the developmental period and the time prior to egg laying. The inner layer would them be the cement-substance covering the eggs following fertilization and prior to storage in the external egg sacs.

d. Histology of the ovisac or egg-string

The wall af the ovisac is not made up of cells but rather of circular fibrous material (Plate 3, fig.23). The outer portion of the wall consists of a dark-staining chitinous layer. The middle portion of the wall consists of a series of alternately light and dark-staining areas. The innermost portion of the wall stains darkly but not as dark as the outside layer. From several places along the surface of the inner layer there are given off strands of material which weave around the eggs in the ovisac.. These strands probably serve to prevent the eggs from crowding each other within the sac. There were from 8-10 eggs in each cross-section. No larval stages were observed.

D. SUMMARY AND CONCLUSIONS

1. The redfish parasite, Sphyrion lumpi (Krøyer 1837) is attached to its host by capsulation of the cephalothorax of the parasite by the host tissue.

2. Specimens of this investigation were obtained from redfish brought to the Boston Fish Pier in October 1948. The number of visible parasites on each infected fish averaged from 2-3. One fish was found to have nine visible parasites (Plate 5, figs. 33 and 34).

3. Bouin's, Zenker's-formol, and 10% formalin were used as fixatives. Serial sections were cut at 8 μ. Stains used were Mallory's triple, iron hematoxylin, Harris' hematoxylin, and phloxine, van Gieson's, and fast green as counter stains. Sections with Bouin's and formalin indicated the best fixation. Harris' hematoxylin with phloxine was found to be the best standard stain.

4. The body wall is made up of two distinct layers, a thick outer non-cellular layer in which the chitin is layed down, and an inner epidermal layer of simple columnar cells.

5. The parenchyma fills the internal cavities not occupied by the internal organs and is more numerous in the regions of the cephalothorax and the posterior processes.

6. The musculature is made up of both longitudinal and dorso-ventral muscle bands. There are eight longituninal bands geginning in the region of the maxillipeds. Four of the bands run dorsally and four ventrally to the gut, all ending at the anterior portion of the rectum. There are strong dorso-ventral muscle bands attached to the degenerate mouthparts. Strong rectal muscles are present in the young forms but less pronounced in the adults. The dorso-ventral muscles of the trunk region are interwoven amongst the

coils of the oviducts and their contractions probably help the eggs along the oviducts.

7. No blood of blood vessels were observed. A system of sinuses is present and probably serves for conduction or circulation od the body fluids.

8. Distinct paired maxilliped excretory glands were observed with a duct leading from one toward the base of the maxillipeds. Small frontal glands were observed in the dorsal anterior portion of the cephalothorax. No ducts were observed here.

9. There were indications of supra-esophageal ganglia. Sub-esophageal and a ventral nerve cord were not observed.

10. Respiration in the young forms probably takes place by contraction of the strong rectal muscles causing suction of water into the rectum. Respiration in the adults probably takes place through the body wall, especially through the dichotomously branched posterior abdominal processes.

11. The gut begins with a short non-protrusible mouth tube which leads to a short and narrow esophagus which is lined with simple columnar epithelium. A stomach is twice as wide as the esophagus and contains numerous folds in the epithelium. A large number of secretory cells are found lining the epithelium and also lying in the lumen of the stomach. On the ventral surface of the gut, two small diverticula are observed, these probably serving to increase the digestive surface. The intestine of the neck region is narrow and contains simple columnar epithelium. However, intra-epithelial glands are observed in the intestinal epithelium of the posterior part of the neck. A complicated system of intestinal processes is present in the trunk region. A single row of processes is given off the dorsal surface which upon reaching the dorsal body wall are profusely branched. One

dorso-lateral and one ventro-lateral row of processes arise from either side of the gut. The dorsal row reaches the inner surface of the dorsal body wall and shows many branchings. The ventral row of processes is also branched and bends ventrally toward the mid-line but does not reach the ventral body wall. Large numbers of secretory cells are found in the epithelium of the intestinal processes and numerous digestive granules appear all over the epithelium and within the lumen of the processes. The lumens of all the processes remain in direct connection with the main line of the intestine. The greatest part of digestion takes place in the intestinal processes of the trunk region. The rectum is short and contains columnar epithelium having numerous crypts. The middle muscular layer of the rectal wall is well developed and indicates a role in respiration. Fecal material was observed in the rectum ensheathed by a membrane shown to be secreted by therectal epithelium.

12. The ovaries are paired and lie in the anterior lateral portion of the trunk. They are arranged into coiled tubes which show from 6-8 ova in each cross-section. There is no free space in the ovary tubules.

13. The ovaries lead to paired, wide, oviducts which are highly convoluted and lead to two external ovisacs at the posterior end of the body.

14. The oviducts contain numerous large developing eggs which have an abundance of yolk and large central vacuoles. Contractions of the dorso-ventral muscles of the trunk region probably help the eggs along the oviducts.

15. Filament cells are associated with the mature ova. Staining indicates their derivation from the ovaries, but no reasonable function is suggested.

16. Paired cement glands are situated in the posterior lateral portions of the trunk. They are tubular in shape and convex toward the mid-line. The

outer portion is cellular and probably secretory in function. The inner portion is non-cellular and constitutes the cement substance derived from the outer layer. No ducts were observed.

17. Paired ovisacs arise from the posterior end of the body. The wall of the ovisac is non-cellular and consists of alternately stained light and dark circular bands. Strands are given off the inner surface of the wall and extend between the eggs of the ovisac and probably function to prevent the crowding of the eggs. Each cross-section showed from 8-10 ova. No larval stages were observed.

18. In order to extend the knowledge of the life history, the host-parasite relationship, and the internal anatomy, it is necessary to observe the larval stages of the parasite and to work out its development. At present no larval stages have been observed. Because of their early activity in finding a host and also because the young forms show a strong musculature, it is quite probable that a study of the developmental forms will show a nervous system. Furthermore, a study of development should indicate the possible damage done by the parasite, a factor which at present has not been clearly established.

III. ABSTRACT OF THE THESIS

An attempt has been made to examine all the literature on the members of the family Sphyriidae Wilson 1919. A short historical account is given together with the classification and distinguishing features of the family. An account is given of the genera and species of the family. The generic and specific features are given of both the females and males(when known). An attempt is made to determine the validity of the species. Figures of the females of each species, taken from various investigators, are given. No figures of the males are given. Two comparative tables are constructed to show in tabulated form the distinguishing features of the males and females of each species.

The second part of the paper is devoted to a description of the internal anatomy of the redfish parasite, Sphyrion lumpi (Krøyer, 1837)Bassett-Smith 1899, based on serial sections of specimens taken from redfish brought to the Boston Fish Pier in October 1948. The description of the internal anatomy includes the body wall, the musculature, the circulation, the excretory organs, the nervous system, means of respiration, the digestive system, and the reproductive system. A description of the histology of the parasite includes the body wall, the parenchyma, muscle histology, histology of the sinuses and the excretory glands, histology of the posterior processes,, histology of the digestive system, histology of the reproductive system, histology of the cement glands, and histology of the ovisacs.Plates containing figures made free-hand and with the aid of the camera lucida are given on both the internal anatomy and histology of the internal organs. A diagrammatic reconstruction (dorsal view) is given showing the position, relationship, and to some extent, the histology of the internal organs.

IV. PLATES AND EXPLANATION OF PLATES

Figures 1-11 are free-hand sketches of the females of the family Sphyriidae taken from various authors.

Plate 1.

Fig.1- Opimia exilis Wilson 1908, ventral view, ♀ , after Wilson (1908).

Fig.2-Paeon versicolor Wilson 1919, ventral view, ♀ , after Wilson (1919).

Fig.3- Periplexus lobodes Wilson 1919, ventral view, ♀ , after Wilson(1919).

Fig.4-Paeon ferox Wilson 1905, ventral view, ♀ , after Wilson (1905).

Fig.5-Rebelula cornuta Wilson 1919, ventral view, ♀ , after Wilson (1919).

Fig.6- Trypaphylum musteli (van Beneden 1851) T. and A. Scott 1913, ventral view, ♀ , after van Beneden (1851).

Fig.7- Rebelula gracilis Wilson 1919, ventral view, ♀ , after Wilson (1919).

Fig.8- Rebelula edwardsii (Kölliker 1853) T. and A. Scott 1913, ventral view, ♀ , head lacking, after T. and A, Scott (1913).

Fig.9- Paeon elongatus Wilson 1919, ventral view, ♀ , after Wilson (1919).

Fig.10- Sphyrion laevigatum Guérin-Menéville 1829, dorsal view, ♀ , after Leigh-Sharpe (1929).

Fig.11- Rebelula bouvieri Quidor 1912, ventral view, ♀ , after Wilson (1919).

Fig.12- Free-hand sketch from a preserved specimen of Sphyrion lumpi (Krøyer 1837) Bassett-Smith, ventral view, ♀ .

KEY TO THE LETTERING USED IN FIGS.1-12.

C - cephalothorax
L - lateral expansions
N - neck
T - trunk
A - abdomen
AL - anal laminae
PP - posterior process
OV - ovisac or egg-string
PI - pit of dorso-ventral muscle
K - knob
P - chitinized process

PLATE I

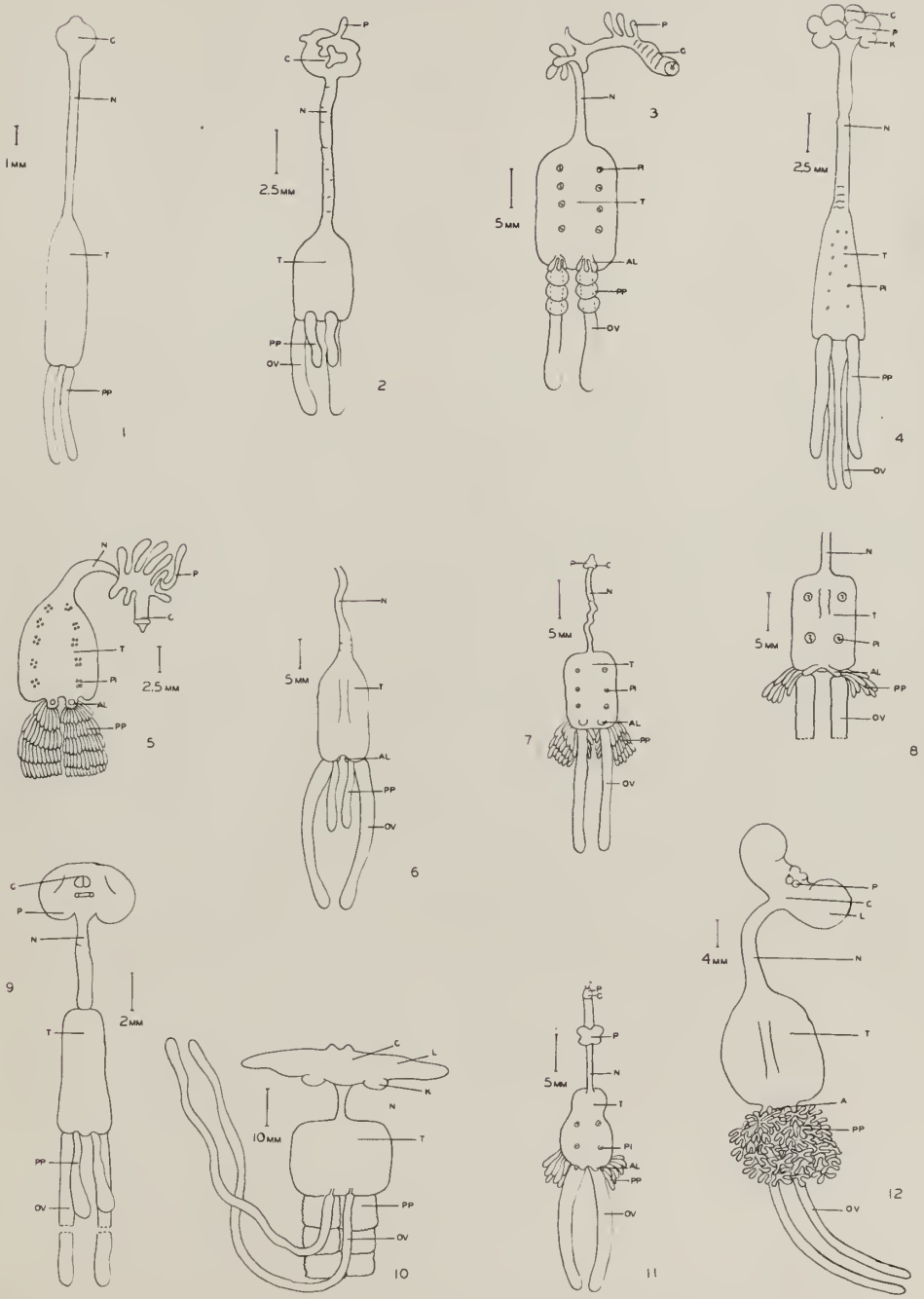
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Plate 2.

Fig.13- Cross section through one maxilliped excretory gland where lobes have merged into a compact-looking gland. Scale B.

M - medullary portion of gland
OU - outer potion of gland
EG - excretory granule
D - duct of the gland
MU - thin muscular wall of duct

Fig.14- Portion of cross section of rectum. Scale B.

OU - outer membrane
M - middle muscular layer
MS - muscular strands
REP - rectal epithelium
CR - crypt of epithelium

Fig.15- Longitudinal section of two dorso-ventral muscle fibers. Scale C.

M - muscle fiber
N - nucleus

Fig.16- Portion of cross section of body wall. Scale C.

CU - outer portion of body wall
EP - epidermis, or inner portion of body wall
P - internal parenchyma tissue

Fig.17- Cross section of a few longitudinal muscle fibers. Scale C.

M - muscle fiber
N - nucleus

Fig.18- Cross section through the esophagus. Scale C.
EEP - epithelium
OU - outer membrane
M - middle muscular layer

Fig.19- Cross section of parenchyma of internal cavities. Scale C.
GN -granulated nucleus
G - small granule
S - sinus or space among the parenchyma cells

Fig.20- Longitudinal section of ovary tubule. Scale C.

O - ovum
N - nucleus
NC - nucleolus

Fig.21- Cross section through the intestine of the neck region. Scale B.

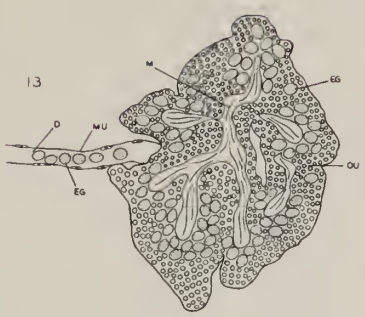
IEP - intestinal epithelium
OU - outer membrane
M - middle muscular layer

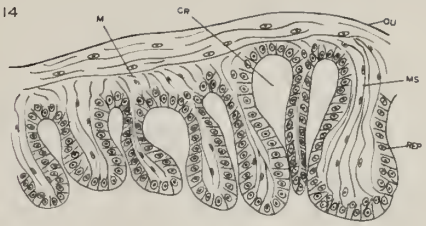
Fig.22- Cross section through ovary tubule. Scale C.
O - ovum
N - nucleus
NC - nucleolus

Fig.23- Portion of cross section of the intestinal processes. Scale B.

IEP - intestinal epithelium
OU - outer membrane
SGC - secretory gland cell
SG - secretory granule
M - middle muscular layer

PLATE 2





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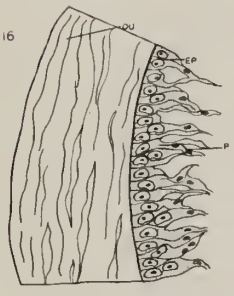

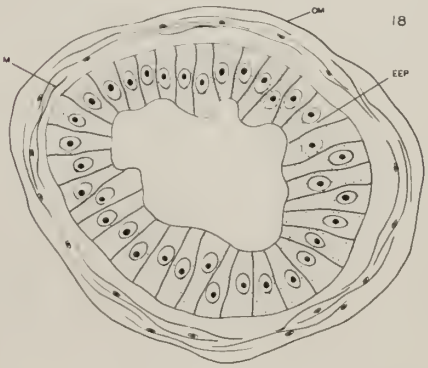

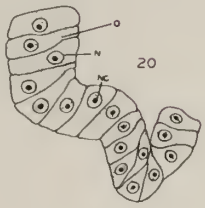

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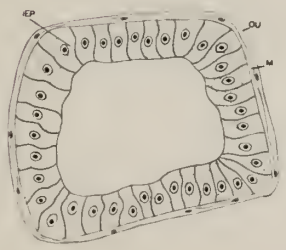


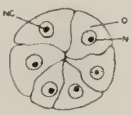


Plate 3.

Fig.24- Cross section through convolutions of oviducts containing developing ova. Scale A.

OV - oviduct
DO - developing ovum
Y - yolk granule
C - central vacuole
P - parenchyma

Fig.25- Cross section through a single unit of the posterior processes. Scale A.

OU - outer portion of body wall
EP - epidermis, or inner portion of body wall
P - internal parenchyma
L - single lamination of outer body wall layer
S - parenchyma cell sinus

Fig.26- Cross section through cement gland. Scale A.

C - chitinized outer layer
OU - outer layer of gland
IN - inner layer of gland
V - vacuole of outer layer
SCL - secreted cement layer

Fig.27- Cross section mouth tube. Scale C.

ME - mouth tube epithelium
P - surrounding parenchyma tissue

Fig.28- Cross section through a single ovisac. Scale A.

OU - outer layer of wall
M - middle layer of wall
IN - inner layer of wall

Fig.29- Cross section through a single expansion of the cephalothorax showing bundles of spongy non-cellilar material.

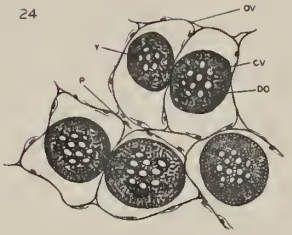
Fig.30- Cross section through the stomach. Scale A.

SEP - stomach epithelium
OU - outer membrane
M - middle muscular layer
S - secretory cell
SG - secretory granule

Fig.31- Cross section through esophagus showing three small sinuses and one large ventral sinus. Scale A.

DE - dorsal sinus
VS - ventral sinus
E - epithelium of esophagus

PLATE 3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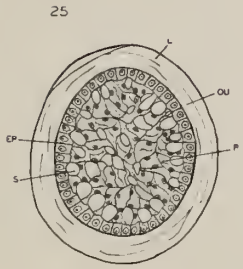
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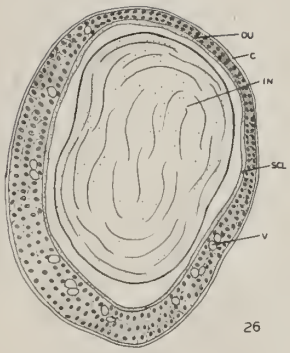
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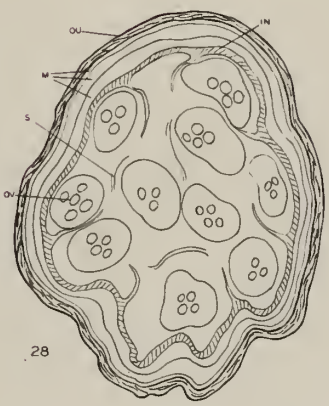
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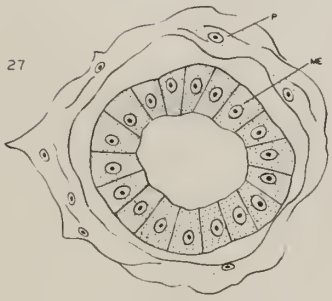
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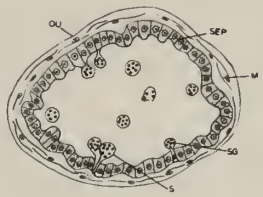
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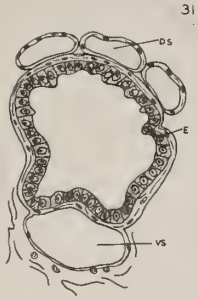
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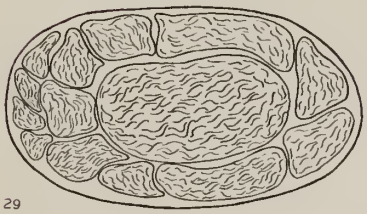
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Plate 4.

Fig.32- Reconstruction of the internal anatomy of Sphyrion lumpi (Krøyer 1837) Bassett-Smith 1899, ♀ . The neck has been foreshortened. Only a portion of the ovisacs are drawn. Only a few units of the posterior processes are indicated. The reproductive system has been pulled out on one side and slightly enlarged.

L - lateral expansions of the cephalothorax
B - bundle of spongy material
M - maxilliped excretory gland
LO - longitudinal muscle band
D - dorso-ventral muscle band
RE - rectal muscle band
MT - mouth tube
E - esophagus
ST - stomach
I - intestine
DI - dorsal row of intestinal processes
DLI - dorsal-lateral row of intestinal processes
VLI - ventral-lateral row of intestinal processes
R - rectum
A - anus
OV - ovary tubule
O - ovum
OVI - oviduct
ES - ovisac or egg-string
PP - posterior process
CG - cement gland
OU - outer layer of cement gland
IN-inner layer of cement gland
P - parenchyma
DO - developing ovum
V - vulva

PLATE 4

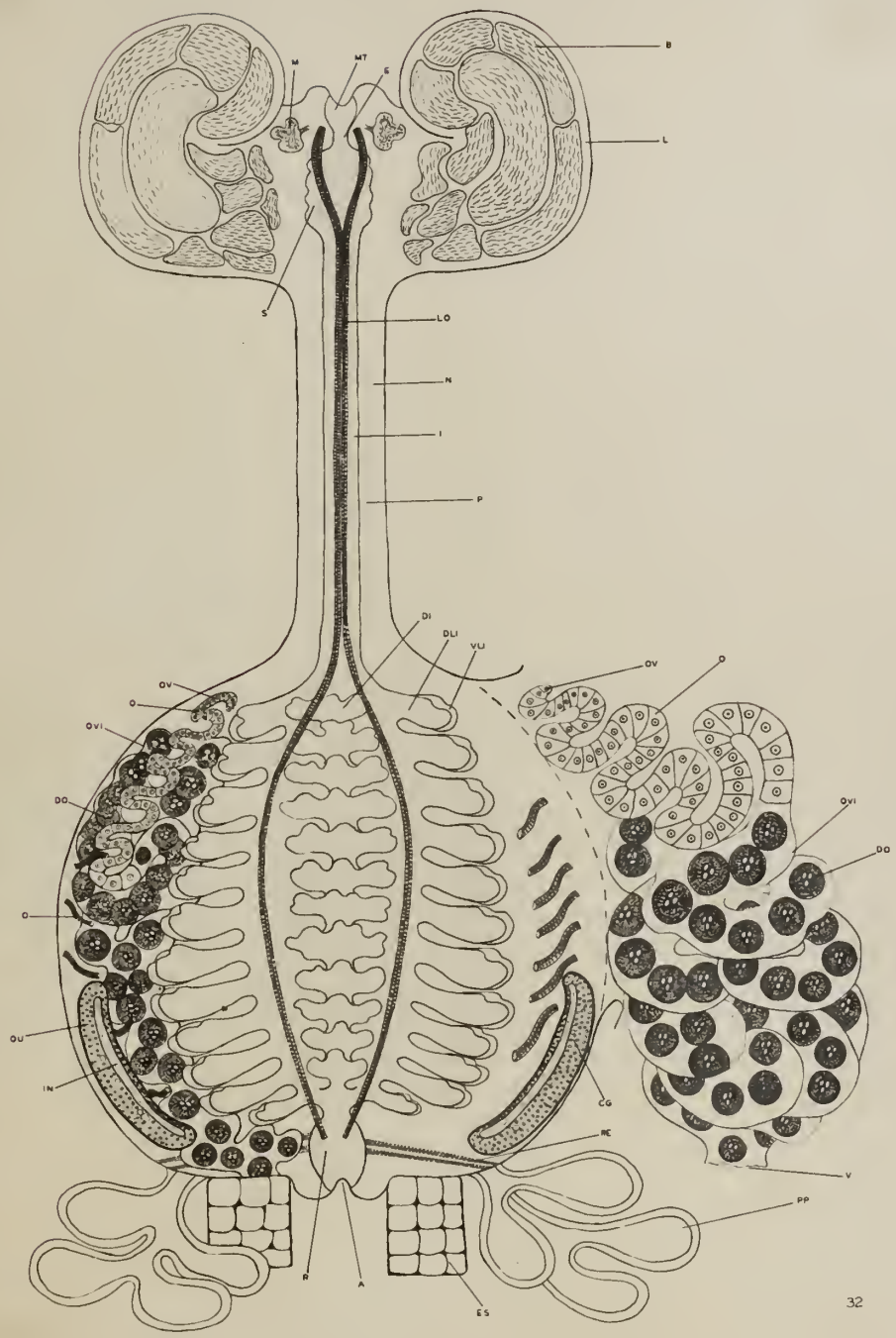

Plate 5.

Figs. 33 and 34 - Photographs of right and left sides of the redfish, Sebastes marinus Linnaeus, showing attachment of nine specimens of Sphyrion lumpi (Krøyer 1837) Bassett-Smith 1899.

PLATE 5.

FIG. 33

FIG. 34

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